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Disciplines

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Current practice in the introduction of solid foods for preterm infants

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Results: When corrected for prematurity, preterm infants received solid foods before the recommended age for the introduction of solid foods for term infants. Median introduction of solid foods for preterm infants was 14 weeks corrected age (range 12–17 weeks). This was significantly less than 19 weeks (range 17–21 weeks) for term infants ($P < 0.001$). Lower maternal education and male gender were associated with earlier introduction of solid foods among preterm infants.

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Keywords

Premature infants
Complementary foods
Introduction of solid foods
Prospective longitudinal study

In 2003 the WHO recommended that infants should be exclusively breast-fed for the first 6 months of life to achieve optimal growth, development and health⁽¹⁾. This guideline was adapted in Australia as part of the 2015 Infant Feeding Guidelines, published by the National Health and Medical Research Council⁽²⁾. Specifically, the guideline states that 'from around 6 months, infants should be offered a range of foods of an appropriate texture and consistency for their developmental stage'⁽²⁾. Other authoritative agencies in Australia and abroad have released similar recommendations regarding the timing of solid food introduction. In 2016, based on emerging evidence regarding the introduction of solid foods and allergy prevention⁽³⁾, the Australasian Society of Clinical Immunology and Allergy revised its infant feeding guidelines to recommend that 'solid foods be introduced from 4 to 6 months of age, when the infant is developmentally ready to start solid foods'⁽⁴⁾ and that allergenic foods should be introduced in the first 12 months of life to prevent the development of allergies.

The 2016 Australian Infant Feeding Summit supported this approach, advising that 'When your infant is ready, at around 6 months, but not before 4 months, start to introduce a variety of solid foods, starting with iron-rich foods'⁽⁵⁾. This 'around 6 months' recommendation has been officially adopted worldwide, with available data in Australia suggesting that the majority of infants are introduced to solid foods between 5 and 6 months⁽⁶⁾.

The timing of solid food introduction is an important issue as research suggests that in addition to prevention of allergies, the timing of solid food introduction may have implications for several health outcomes. Recent studies report that early introduction of solid foods is associated with longer sleep duration, less frequent waking at night and a reduction in serious sleep problems⁽⁷⁾. The introduction of solid foods before 4 months is not recommended due to an associated increase in risk of allergy⁽⁸⁾ and childhood obesity^(9–11). It has also been hypothesised that early microbiota may be affected by the introduction

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of solids and mediate this potential link to childhood overweight⁽¹²⁾.

However, whether current guidelines apply to the preterm infant is not clear, as there is insufficient evidence regarding the timing of solid food introduction to preterm infants and the associated health-related outcomes⁽⁵⁾. Preterm infants are more likely to be growth-restricted compared with term infants and to have altered body composition at term-equivalent age compared with the term infant⁽¹³⁾. The preterm infant may have increased nutritional requirements, but is also at risk of respiratory problems, gastro-oesophageal reflux and developmental delay. Early introduction of solid foods may assist with meeting these increased nutritional requirements and may assist in oral motor development. Again, however, there may be an association with rapid weight gain and childhood obesity for this group⁽¹¹⁾.

Recommendations for the introduction of solid foods to the preterm infant vary between sources^(14–16). In the UK, the Department of Health suggested that solid foods should be introduced once the infant reaches 5 kg body weight, the extrusion reflex is lost and s/he is able to eat from a spoon⁽¹⁷⁾. Later, the American Academy of Family Physicians suggested that solid foods could commence around 4 to 6 months corrected age (the age of an infant based on due date) and once the infant was oral-motor ready⁽¹⁸⁾. Based on a compromise to balance the nutritional benefits of commencing solid foods from 13 weeks of uncorrected age with the risks of increased eczema development, along with ensuring developmental readiness, Palmer and Makrides⁽¹⁵⁾ suggested that 3 months (13 weeks) corrected age was an appropriate age for introducing solid foods in preterm infants⁽¹⁵⁾. In contrast, Gupta *et al.*⁽¹⁹⁾ recommended 6 months for introduction of solid foods in preterm infants born at less than 34 weeks' gestation, based on a higher rate of hospital admissions in a 4-month introduction group⁽¹⁹⁾. That study was conducted in a lower-income country and therefore generalisability to higher-income countries is uncertain.

A number of factors that influence the timing of solid food introduction in the preterm infant have been described. Maternal factors, such as age, pre-pregnancy BMI and education, along with milk type and infant factors, such as birth weight and gestational age, may influence the age of solid food introduction^(14,20). In the term infant, reasons for early introduction of solid foods (<4 months of age) were explored in a study in the USA⁽²¹⁾. Maternal perception of infant readiness, hunger, increased interest in solid foods, in addition to advice from a clinician and to improve the infant's sleep, were all said to be drivers of early introduction of solid foods. Several of these reasons varied depending on the type of milk feeds the infant was receiving (breast-fed, mixed and formula-fed infants)⁽²¹⁾. Another US study found that early introduction of solid foods was correlated with mother's beliefs about

early feeding before 6 months of age as well as the influence of infant temperament⁽²²⁾.

There have been no recently published data in Australia on the introduction of solid foods to preterm infants, with previously reported studies coming from the USA, UK and Europe. Historically there are significant variations in the timing reported between countries^(14,20,23,24); these vary between 11.5 and 15.1 weeks corrected age. The present study was developed based on previous longitudinal studies^(14,20) to update the current feeding practices for preterm infants in a developed country.

The present study thus aimed to determine the age of first solid foods in preterm infants compared with term infants and the factors associated with this, specifically: (i) the age (weeks) of first solid foods in preterm infants compared with term infants; (ii) the proportion of infants introduced to solid foods early (<17 weeks); and (iii) the factors associated with the introduction of first solid foods for preterm infants.

Materials and methods

Study design and participants

This was a prospective, birth cohort study in the Illawarra region of New South Wales, Australia. Prematurity was defined as infants born less than 37 weeks and 0 d of gestation. The introduction of solid foods was defined as the time when solid food (defined as semi-solid, soft or solid foods other than breast milk, formula or other milk) was offered on a daily basis. Both term and preterm infants were recruited from a public, metropolitan, regional referral hospital maternity ward and the associated neonatal unit from June 2014 to March 2016. The neonatal unit is a twenty-bed, level 4 unit providing care to preterm infants from 32 weeks' gestation. It is a feeder and follow-up unit from higher-level neonatal units, so the majority of preterm infants living in this area are discharged home from this unit. This was a convenience sample of parents and/or carers, dependent on consent and availability of study personnel. Once per week parents of infants who met the research criteria were approached and, if they agreed to comply with the study schedule, consent was obtained.

Exclusion criteria were preterm and term infants with conditions that were likely to interfere with feeding, such as major congenital malformations, neurological conditions or substance withdrawal.

Data collection

Mothers were interviewed in the hospital by a paediatric dietitian shortly after birth (in hospital) and at 3, 6, 9 and 12 months corrected postnatal age (in hospital or by telephone or email). Structured interview questionnaires were developed and tested for face validity prior to

implementation. Additional information was extracted from obtained hospital medical records for all time points. Baseline data were taken at birth (for term infants) and term equivalence (for preterm infants), including: maternal age, maternal country of birth, maternal self-reported pre-pregnancy BMI, level of education and infant gender, gestational age at birth, birth weight, medical history and head circumference. Infant feeding practices at birth admission (type of milk, feeding method) were also documented.

Data collected at subsequent time points included growth parameters (weight, length and head circumference), medical diagnoses and current feeding practices. Structured interviews covered milk type, the age of solid food introduction (chronological), and the type (food group) and order of first solid foods. A 24 h recall of the infant's food intake was also collected at each time point. Additional qualitative information regarding the introduction of solid foods was also obtained, including the attitudes and beliefs that affected the parent's decision to introduce foods, as well as who guided and/or provided advice concerning timing and type of foods. Participants who were unable to be interviewed in person or over the telephone were contacted via email and provided with an online version of the questionnaire.

Statistical methods

Using proportion being fed solid foods at <17 weeks corrected age from historical studies, a sample size calculation suggested sixty-five infants in each group, using 85% power and α of 0.05. As completion rates were not known in advance, oversampling was undertaken initially. Final analyses were restricted to those participants who provided data on the primary study outcome, age of solid food introduction. De-identified data were analysed using the statistical software package IBM SPSS Statistics version 21. Mann–Whitney and χ^2 tests were conducted to explore differences in characteristics and outcomes of preterm and term infants, with significance set at $P < 0.05$.

Univariate analysis of factors associated with early introduction in preterm infants included gender, gestational age (<33 weeks/33–36 weeks), birthweight percentile (<10%/10–90%/>90%), maternal education (<Year 12/ \geq Year 12), maternal BMI (≤ 25 / >25 kg/m²) maternal age (<30/ \geq 30 years) and milk type (exclusive breast milk/other) at baseline, 3, 6, 9 and 12 months.

Stepwise regression with backward elimination was performed to model the significant influences on the age of solid food introduction in preterm and term groups, respectively. For preterm infants, variables included were milk type at baseline, sex, birth percentile, gestational age, mother's age, BMI and education. For term infants, variables included were milk type at baseline, sex, birth percentile, and mother's age, BMI and education.

Results

Maternal and infant characteristics

Baseline characteristics of the preterm and term infants and their mothers are described in Table 1. There was no significant difference between groups by mother's age or formal education. There was an unexpected difference in reported pre-pregnancy BMI, with the preterm group having more mothers in the healthy weight category ($P = 0.046$). As expected, there was a larger proportion of male infants than females in each group, reaching significance for the preterm group ($P = 0.046$), but the proportion of males was not significantly different between the term and preterm groups. There was a significantly lower birth weight percentile for the preterm group, reflecting the pathologies leading to preterm delivery.

Age at introduction of solid foods

Solid foods were introduced to preterm infants at a median of 21 weeks post-delivery (range 18–24 weeks) which, although significantly later than the median of 19 weeks (range 17–21 weeks) of term infants ($P < 0.002$; Fig. 1), was found to be significantly earlier than for term infants when corrected for prematurity at birth: 14 weeks (range 12–17 weeks; $P < 0.0001$; Fig. 1). Seventy-one (83%) preterm infants were introduced to solid foods before 17 weeks corrected age, compared with twenty-six (40%) term infants ($P = 0.001$). By 6 months corrected age nearly all infants (96.7%) were receiving solid foods, with no difference in the proportion being fed solid foods between groups.

Factors associated with age of solid food introduction

In our preterm population of infants, lower maternal education level and male gender were associated on univariate analysis with earlier introduction of solid foods (Table 2). Neither milk type nor birth percentile was associated with the age at introduction of solid foods (data not shown).

In term infants, lower maternal education (<Year 12) and younger maternal age (<30 years) were associated on univariate analysis with earlier introduction of solid foods (Table 2).

Stepwise regression models were conducted to determine which factors predicted the age (weeks) of introduction of solid foods while controlling for all other variables. Only male gender and lower maternal education (<Year 12) were significant factors predicting earlier introduction of solid foods for preterm infants (Table 3). Similarly, for term infants, male gender (borderline significance), lower maternal education (<Year 12) as well as younger maternal age were significantly associated with the earlier introduction of solid foods.

Rice cereal (68%) was the most common first solid food offered to the infant, with fruit (18%) and vegetables (12%)

**Table 1** Baseline characteristics of mothers and infants from a regional metropolitan referral hospital in the Illawarra region of New South Wales, Australia, June 2014–March 2016

	Preterm (<i>n</i> 85)		Term (<i>n</i> 65)		
	Median or <i>n</i>	IQR or %	Median or <i>n</i>	IQR or %	<i>P</i> value
Mother					
Age (years)	30.7	28.4–35.5	30.2	26.1–35.6	0.39
BMI†,‡ (kg/m²)	22.0	20.3–27.2	24.9	21.1–27.8	0.03
Healthy (<25 kg/m²)	52	61	29	45	
Overweight (≥25 kg/m²)	25	29	30	46	
Maternal education‡,§					0.57
<Year 12	44	52	31	48	
≥Year 12	40	47	34	52	
Maternal country of birth					0.42
Australia	80	94	60	92	
China	2	2	1	2	
Europe	2	2	1	2	
Indonesia	1	1	0	0	
India or Pakistan	0	0	2	3	
Palestine	0	0	1	2	
Infant					
Gestational age (weeks)	33.5	32.0–35.2	39.0	38.1–40.1	0.001
Birth weight (kg)	2.0	1.6–2.3	3.3	3.0–3.7	0.001
Birth length (cm)	43.5	41.0–46.0	50.0	48.0–51.0	0.001
Birth percentile	28.0	14.0–53.0	55.0	25.0–83.0	0.001
SGA (<10 %)	13	15	10	15	
AGA (10–90 %)	70	82	47	72	
LGA (>90 %)	2	2	8	12	
Gender					0.14
Male	56	66	35	54	
Female	29	34	30	46	

IQR, interquartile range; SGA, small for gestational age; AGA, appropriate for gestational age; LGA, large for gestational age.

Continuous data are presented as median and IQR, categorical data as *n* and %.†Preterm, *n* 77; term, *n* 59.

‡The percentages for maternal BMI sub-categories (healthy and overweight) and maternal education (preterm infants) do not add up to 100 % due to missing data.

§Preterm, *n* 84.

||The percentages for maternal country of birth and birth percentile do not add up to 100 % due to rounding of percentage values.

also offered as a first foods. When parents were asked about the main governors of solid food introduction for their infant, the most cited influences were perception of milk not satisfying the infant; the infant appeared developmentally ready for solid foods; and from advice of health professionals (paediatricians and dietitians ranked most frequently).

Discussion

This cohort of preterm infants (*n* 85) in Australia commenced solid foods at 14 weeks (corrected age), corresponding to 21 weeks (chronological age), which was significantly earlier than the 19 weeks for term infants. This finding is similar to other studies conducted previously in the UK, Europe and the USA^(14,20,23,25). The US longitudinal study conducted in 2001 (but reported after our study commenced) determined that in the USA solid foods were introduced to preterm infants at a corrected age of 13 weeks and to term infants at 17 weeks⁽²³⁾. Two previous observational studies, restricted to preterm infants, showed both earlier and later introduction of solid foods: a UK study

estimated that complementary feeding among preterm infants commenced at 11.5 weeks corrected age⁽²⁰⁾; and a similar preterm study from Italy reported that solid foods were offered slightly later, at 15 weeks corrected age, in their population⁽¹⁴⁾. A recent German national survey of parents of very-low-birth-weight infants had an average of 15 weeks, 6.5 weeks earlier than term infants⁽²⁵⁾. These timing differences have been attributed to differing local recommendations, environmental factors, parental cultural beliefs and attitudes towards introducing solid foods specific to each country^(14,23,26,27). Regardless of the variations in the timing between countries, research thus consistently confirms our findings, with large proportions of the preterm population, ranging from 40 to 98 %, commencing solid foods before the recommended age when adjusting age for prematurity^(14,20,23–26,28).

Parents of preterm infants, or their professional advisors, appear not to be adjusting for prematurity when introducing solid foods. Most guidelines state that preterm infants should be corrected for prematurity until 2 years of age^(29,30), as the development of fine and gross motor skills, cognition and growth among the preterm population is dependent on corrected age and this continues into early

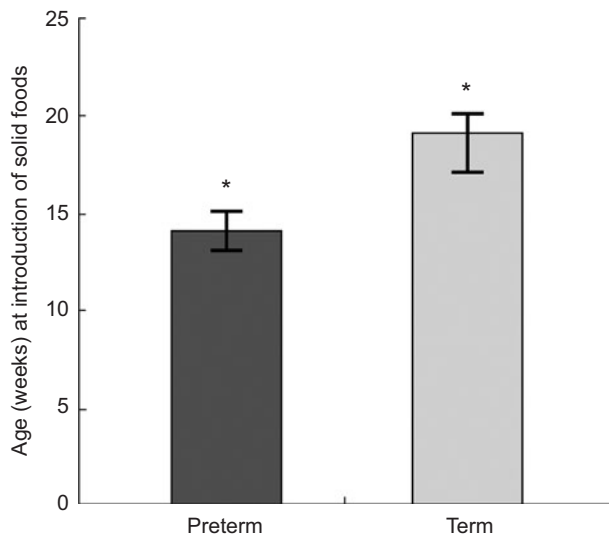


Fig. 1 Age (weeks) at introduction of solid foods in preterm† ($n = 85$) and term infants ($n = 65$) from a regional metropolitan referral hospital in the Illawarra region of New South Wales, Australia, June 2014–March 2016. Values are medians, with their 95 % CI represented by vertical bars. *Significant difference between groups: $P < 0.05$. †Corrected for prematurity in weeks post due date

childhood^(29,31,32). Introducing solid foods to premature infants before they have developed the necessary fine and gross motor skills may be unsafe and may contribute to the long-term abnormal feeding behaviours more commonly seen in these populations^(33–35). This failure to correct for prematurity has been documented among health-care providers. D’Agostino *et al.*⁽³⁶⁾ found for the majority of child care visits that primary care providers were not adjusting for prematurity and almost one-third of paediatricians were not informing parents of their infant’s corrected age⁽³⁷⁾. Thus, advice to parents on age of commencing solid foods was earlier than recommended guidelines^(36,37).

Suggestions that introducing solid foods before 4 months of age may increase the risk of chronic conditions such as obesity are currently being explored⁽¹¹⁾, with recent research finding no significant difference in BMI Z-score at 1 year between early and later introduction of solid foods in preterm infants⁽¹¹⁾. Another study, by Spiegler *et al.*⁽²⁵⁾, also found the early introduction of solid foods did not negatively influence length or weight gain in very-low-birth-weight infants⁽²⁵⁾. In contrast, Pluymen *et al.*⁽³⁸⁾ found the prevalence of overweight throughout childhood was higher in children with introduction of solid foods before 4 months (with a higher risk in formula-fed infants and those breast-fed for <4 months)⁽³⁸⁾. It has thus been suggested that any obesity association may be more of a risk in older gestational age preterm infants with no co-morbidities than in those of earlier gestational age⁽³⁹⁾. More recently, researchers have identified that preterm infants have altered body composition, characterised

predominantly by less fat-free mass but a maintained fat mass, leading to a greater percentage total body fat^(13,40,41). Further research into the childhood and later-life obesity risks of timing of the introduction of solid foods is required in these at-risk populations.

The appropriate time to commence solid foods in the preterm infant is unclear⁽⁵⁾ and may not be the same as for the term infant, as there are a number of preterm-specific factors to be considered. Fetal nutrient accretion peaks during the third trimester of pregnancy. Premature infants thus have limited nutrient stores at birth⁽⁴²⁾. Some infant feeding guidelines recommend that meat, fish, poultry, tofu, legumes or iron-enriched infant cereal should be among the first foods introduced, prior to fruit, vegetables and dairy, to address the perceived inadequacy of milk diets in meeting the nutritional requirements of premature infants, in particular for iron and zinc⁽²⁾. The potential consequence of preterm infant deficiencies, such as anaemia of prematurity, are known but also apply to other tissue growth, including the brain⁽⁴²⁾. Despite this, both our study and others suggest the first foods offered are consistently poor sources of energy, protein, iron and zinc^(14,20). Recent studies in both lower- and higher-income countries also identified that first foods are often less energy-dense and require the infant to consume more to meet energy needs^(19,25). Furthermore, it has been suggested that these compositional dietary differences, rather than timing, may be more of an obesity risk⁽²⁵⁾. High energy and dairy protein in infancy have been associated with increased infant fat mass and these changes may be mediated by differences in gut microbiota⁽¹³⁾.

A number of maternal factors have been identified in the literature as predictors of early introduction of solid foods, including younger age, a lower level of educational attainment and higher BMI^(14,20,23,43,44). In the present study only lower maternal education was a significant predictor of earlier introduction of solid foods. Other factors identified in the literature to predict early introduction of solid foods include smoking, low socio-economic status, previous children and milk feeding practices^(14,23,26,28,44), all of which are known to be associated with maternal education level. The influence of milk feeding practices in the present study was found to be similar to other studies, with breast-fed infants more likely to have solid foods introduced later. Consistent with other studies the only infant characteristic that was significantly associated with the timing of solid food introduction was gender. Males were significantly more likely to commence solid foods earlier than females, but it is not known if this is due to cultural or biological influences^(14,20).

The main reasons given by mothers in our study for when solid foods were introduced were the perception that milk was not satisfying the infant, that the infant was developmentally ready or following the advice given by a health professional. These reasons were similar to those given in studies of term infants⁽²²⁾. There is some evidence in the literature of a perception of the importance of ‘catch-up’

**Table 2** Univariate maternal, infant and feeding factors in relation to age in weeks at introduction of solid foods in preterm† and term infants from a regional metropolitan referral hospital in the Illawarra region of New South Wales, Australia, June 2014–March 2016

Factor	Preterm (n 85)			Term (n 65)		
	Median	IQR	P value	Median	IQR	P value
Gender						
Male	13.0	11.0–16.0	0.019*	18.0	17.0–20.0	0.58
Female	15.0	13.0–18.0		19.5	17.0–22.0	
Gestational age						
<33 weeks	14.0	10.0–17.0	0.812	N/A		N/A
33–36 weeks	14.0	12.0–16.0		N/A		N/A
Birth percentile						
SGA (<10%)	15.0	13.0–17.0	0.930	18.5	17.0–21.0	0.159
AGA (10–90%)	14.0	12.0–16.0		19.0	17.0–21.0	
LGA (>90%)	14.0	11.0–17.0		22.0	19.0–22.5	
Maternal education						
<Year 12	13.0	10.0–16.0	0.012*	17.0	16.0–20.0	0.009*
≥Year 12	14.0	13.0–18.0		19.5	17.0–22.0	
Maternal BMI						
Healthy weight	14.0	11.5–17.0	0.320	19.0	17.0–21.0	0.516
Overweight or obese	15.0	13.0–17.0		19.0	16.0–21.0	
Maternal age						
<30 years	14.0	11.0–16.5	0.569	17.0	17.0–19.0	0.001*
≥30 years	14.0	12.0–17.0		21.0	18.0–23.0	

IQR, interquartile range; SGA, small for gestational age; AGA, appropriate for gestational age; LGA, large for gestational age; N/A, not applicable.

*Significant at $P < 0.05$.

†Corrected for prematurity in weeks post due date.

Table 3 Multiple regression of factors associated with the age in weeks at introduction of solid foods in preterm† and term infants from a regional metropolitan referral hospital in the Illawarra region of New South Wales, Australia, June 2014–March 2016

Cohort	Factor	B	SE (B)	β	P value
Preterm	Gender	1.9	0.9	0.2	0.038*
	Maternal education	1.9	0.9	0.3	0.026*
Term	Gender	1.6	0.8	0.2	0.053
	Maternal age	2.3	0.9	0.3	0.012*
	Maternal education	1.8	0.9	0.3	0.043*

B, unstandardised regression coefficient; SE(B), standard error of the coefficient; β , standardised coefficient.

*Significant at $P < 0.05$.

†Corrected for prematurity in weeks post due date.

growth for the preterm population and a need to meet developmental milestones similar to that of term babies, i.e. a failure to correct temporal expectations for the degree of prematurity⁽⁴⁵⁾.

There are some limitations to our study. The data were limited to a convenience sample within our health district and thus might not be generalisable to the larger Australian or international population. Our area is, however, highly representative of national cohorts⁽⁴⁶⁾ and our results are largely consistent with international findings. Maternal demographic data and infant feeding practices were self-reported and so subject to the usual limits of recall bias. Study strengths include prospective recruitment^(47,48) in a public hospital environment, thus including those born over a full range of socio-economic circumstances. Our level 4 neonatal unit accepts preterm infants from higher

level 5/6 units and therefore we were able to obtain a representative sample of preterm infants living in the Illawarra area. Our study is in a non-US, non-European environment but consistent with findings from these areas. There is little information to guide the application of these findings to emerging economies, where the risks of increasing obesity and other non-communicable diseases are escalating and where weaning practices are starting to be examined for these populations⁽¹⁹⁾.

Our study demonstrates the current feeding practices of preterm infants at weaning. We have confirmed that infants born prematurely are still introduced to solid foods well before the recommended age for term infants, without clear evidence of the benefits or risks associated with this practice. Further larger studies into the specific characteristics of preterm infants that might affect the introduction of solids, such as medical conditions at birth and at the time of solid food introduction, Apgar scores and days to reach full enteral feeds, are required. The ideal timing of introduction of solid foods to the preterm infant needs to be studied further in respect to allergy prevention, reducing the risk of childhood or later-life obesity, reducing the risk of hospitalisation and optimisation of the microbiota. In addition, studies should be conducted on nutritional composition of first foods, as this may also affect obesity risk, fat mass, nutrient intakes and changes in microbiota. Finally, these studies need also to be undertaken in the emerging economic areas, where the potential effects of future disease are huge.

The present study highlights some of the maternal and infant predictors of early solid food introduction, which

could be used in practice to identify those at risk of early solid food introduction. It also highlights the need to educate health professionals in the use of prematurity corrected age so that advice provided for preterm infants is consistent and developmentally appropriate. Although the lack of evidence for specific feeding practices for preterm infants leads clinicians to base recommendations on the degree of prematurity, growth patterns, nutritional requirements and developmental readiness, the present study highlights the need for further research to determine an evidence base for the recommendations for preterm infants.

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